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EVALUATING BUSINESS PROCESS IMPROVEMENT PATTERNS BY SIMULATION

Complete Research

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Abstract

Existing approaches for business process improvement often lack systematic guidelines to transform a business process into an enhanced state, which we refer to as the "act of improvement". To close this gap, a pattern-based approach has been designed and developed in previous works. In this paper, the usefulness of "Business Process Improvement Patterns" (BPI-Patterns) as a means of improving business processes is analyzed. For this purpose, a simulation experiment is performed in which several BPI-Patterns are applied to evaluate whether their anticipated effects can be confirmed for real-life business processes. From the analysis of the simulation results, i.e. how the application of BPI-Patterns affects the business processes, we investigate enabling as well as hindering factors that influence the implementation of BPI-Patterns. These factors may serve as a means to further specify instances of BPI-Patterns and also contribute to the overall evaluation of the BPI-Pattern approach.

Keywords: Business Process Improvement, Pattern, Evaluation, Simulation.

1 Introduction

Nowadays business process management (BPM) plays a crucial role in the daily routines of organizations (Jansen-Vullers and Netjes, 2006, Kohlbacher, 2013, Smirnov et al., 2012). New emerging technologies, higher competition, and changing customer demands are challenging tasks that organizations have to meet (Boerner et al., 2012). To deal with these challenges, companies need to organize their work routines, the so-called business processes, in an efficient way (Fuglseth and Gronhaug, 1997, Sidorova and Isik, 2010). The concept of BPM leads to an increase of productivity, quality, and innovation (Minonne and Turner, 2012). Many approaches dealing with the improvement of these business processes were introduced (Andersson et al., 2005). However, most of these existing approaches lack the description of what changes are exactly needed within a business process to reach a desired "to-be"-process (Griesberger et al., 2011, Nwabueze, 2012, Rjinders and Boer, 2004, Snee, 2010). We refer to these changing procedures as the "act of improvement".

To bridge the aforementioned gap, a pattern based approach was developed along with generic BPI-Patterns for the improvement of business processes (Falk et al., 2013a). The overall research project follows the design science research (DSR) paradigm, which strives for creating new and innovative solutions, the so-called artifacts, for a specific problem domain (Goes, 2014). Patterns in general propose plans or structures that are abstracted from reality to reach a predefined goal (Paludo et al., 2000).

Thus, similar to patterns from other fields of information systems, e.g. like patterns for software development, BPI-Patterns aim at improving business processes by providing reusable solutions for typical, recurring problems. The key is that these BPI-Patterns describe what exactly has to be done to solve a specific problem in a business process, as they contain instructions how to transform a business process from its "as-is" to a desired "to-be"-state.

After establishing the conceptual ground work of BPI-Patterns and deriving single instances of BPI-Patterns, the crucial task is now to show that the concept of BPI-Patterns is effective and useful. It corresponds to the evaluation being a key component of DSR that assesses the utility of artifacts created for solving problems of the problem domain (Venable and Baskerville, 2012). Therefore, instances of BPI-Patterns are investigated as they comprise the actual instructions that are meant to bring about improvement. In doing so, certain requirements or enablers for their successful application and, at the same time, factors of influence that hinder successful applications of BPI-Patterns may be discovered. Findings from this analysis serve as a basis for the supplementation of the existing BPI-Pattern instances. To show this, a simulation of applying BPI-Patterns on real-life processes (application procedure for specific degree courses at a university's deanery) is performed, which enables statements about their meaningfulness. Essentially, that analysis is based on comparable quantitative results of costs and times. Beforehand, the configuration of a simulation approach that meets the requirements of being used to evaluate BPI-Patterns will be addressed. This examination of the application of BPI-Patterns contributes to the overall evaluation of the BPI-Pattern approach.

The remainder of this paper is organized as follows. In section 2, essential topics and terms are introduced. The overall research methodology is presented in section 3. The proposed simulation methodology for evaluating BPI-Patterns is described in section 4. An actual simulation of applying BPI-Patterns on real-life business processes is shown in section 5, along with a discussion of remarkable results in section 6. Based on the simulation results, inferences for possible revisions of the BPI-Patterns are drawn in section 7. Finally, section 8 concludes the paper.

2 Theoretical Background

2.1 Business Process Improvement

Davenport and Short (1990) define a business process as a "set of logically related tasks performed to achieve a defined business outcome". By systematically reorganizing these related tasks, organizations are able to significantly influence the way of doing their business (Forster, 2006). Different approaches were developed for this task, e.g. business process reengineering (BPR), in which "as-is"-processes are removed to be redeveloped from scratch (Hammer and Champy, 1993). In contrast, the concept of BPI maintains the current "as-is"-processes and focuses on incremental improvements by changing the existing process design to make it more effective, efficient, and adaptable (Harrington, 1991), i.e. transforming a process into a desired "to-be"-process. Transformation steps recurring in several BPI initiatives may constitute a pattern of a successful improvement measure.

2.2 Business Process Improvement Pattern

The concept of patterns as the documentation of proven knowledge that has already worked to solve problems within a specific context is very popular in the field of IS (Buckl et al., 2013). Regarding their reusability aspects, the attraction of using patterns lies in e.g. shorter development times and lower costs of new solutions (Tran et al., 2006), while they also facilitate an efficient transfer of skills and expertise within a specific context (Behnam and Amyot, 2013). Reusing proven knowledge to improve the performance of business processes is also a common approach (Andersson et al., 2005) and several authors have explicitly addressed the topic of BPI-Patterns. A framework for the classification of BPI-Patterns is proposed by Forster (2006) and presented together with some exemplary patterns based on generic process modification steps. Reijers and Limam Mansar (2005) provide a collection of best practices in business process redesign that are derived from literature and practical experience. They also used the four categories cost, time, quality, and flexibility to assess their effects on process performance. Kim et al. (2007) examined how BPM can be supported by business process change patterns that enhance the flexibility of BPM approaches. A more comprehensive literature review covering different types of BPI-Patterns as well as patterns in other fields of information systems is provided in Falk et al. (2013a).

To formalize the specification of BPI-Patterns and to facilitate their reuse, a description template was developed (Falk et al., 2013a). It basically consists of a problem description, the measures that should be taken to apply the BPI-Pattern, and an assessment of the anticipated effects on cost, time, quality, and flexibility. Figure 1 shows the data model of a BPI-Pattern and the contained attributes together with their mutual relationships. On this basis, several instances of BPI-Patterns were derived and their functioning already demonstrated (Falk et al., 2013b).

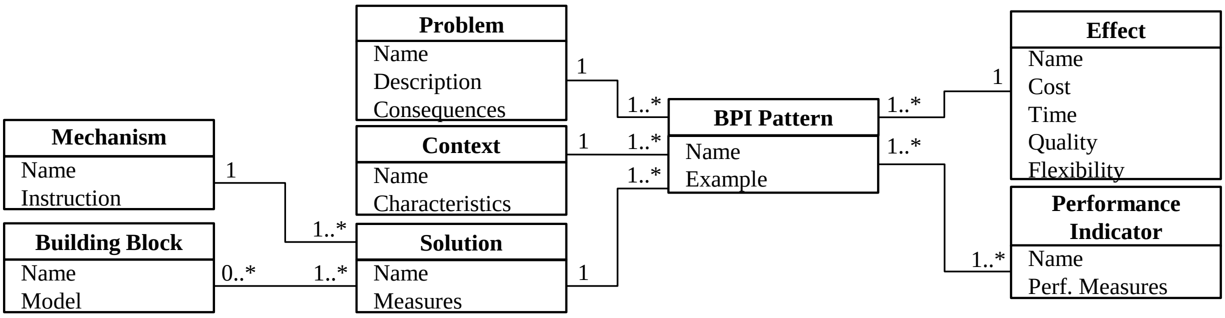

Figure 1. Data Model of a BPI-Pattern (Falk et al., 2013a)

The three BPI-Patterns that are used for simulation purposes in the paper at hand, are described in more detail in section 5.2. Beyond that, other typical examples of BPI-Patterns are:

- “Divide complex processes into smaller sub-processes”: An overloaded process flow is straightened out and reorganized into logical segments that are easier to understand and manage. Thus, improvements regarding time, quality, and flexibility are expected because of the reduction of waiting times, decreased error rates due to a clear process design, and well-defined interfaces between the sub-processes, respectively.
- “Combine activities that show overlapping tasks”: Similar or closely related activities that are located at various places within a business process or being performed by different people are combined to a single activity producing an equivalent output. Since overhead as e.g. set-up costs or set-up times can be reduced, improvements in the categories cost and time are expected.
- “Dissolve bottlenecks on the critical path of a process”: The capacity of each bottleneck activity is adjusted and balanced by e.g. relocating existing resources or deploying additional resources with the result that the throughput of the whole process reaches an optimum. By reducing of waiting queues, especially improvements in terms of cycle time may be achieved.

For the selection of a suitable pattern instance depending on an individual problem situation, a generic procedure for selecting BPI-Patterns has been suggested (see (Falk et al. 2013b). Seeking a suitable BPI-Pattern can be started with a search either for patterns with appropriate problem statements or for patterns which lead to the desired effects. Regardless of how one begins, both of these steps have to be executed consecutively. Next, the context statements of the remaining patterns have to be checked for influencing factors which facilitate or prevent the application of a BPI-Pattern. If, after this step, several patterns remain, they have to be prioritized according to the underlying situation to determine the most suitable one(s), which can ultimately be applied in the BPI project.

3 Research Methodology

Our research on BPI-Patterns follows the design science research methodology (DSRM) by Peffers et al. (2007), which comprises six steps as shown by Figure 2. DSRM-steps 1 to 4 were the subject of previous research papers. The BPI-Patterns were designed on the basis of a literature review, which aimed at defining the core elements needed for their description (see (Falk et al., 2013a)). After defining the structure, single instances of BPI-Patterns were derived from multiple sources and their effects were demonstrated and partly evaluated by means of a case study (see (Falk et al., 2013b)). However, the evaluation of the BPI-Pattern approach is still the subject of ongoing research. Griesberger (2014) showed that within the BPI-Pattern approach several artifact types can be distinguished, namely "model", "instantiation", and "method". He proposed a comprehensive evaluation method taking into account these different artifact types that are part of the BPI-Pattern approach.

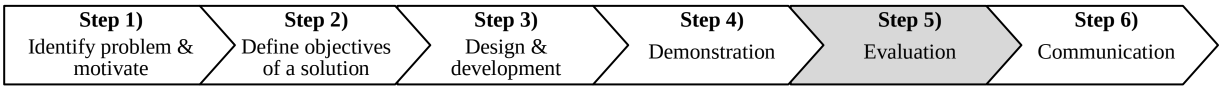

Figure 2. Design Science Research Methodology (DSRM) (Peffers et al., 2007)

Our paper contributes to DSRM-step 5 (evaluation) and investigates the effectiveness of BPI-Patterns to improve business processes. In general, there is a multitude of possible DSR evaluation methods (Peffers et al., 2012). However, evaluation is often poorly performed (Pries-Heje et al., 2008), and there is little guidance as to how to actually perform it in a given DSR situation (Ostrowski and Helfert, 2012). The evaluating activity assesses the novelty of the created artifact for the underlying problem domain and compares the objectives of the solution to the actually observed results (Mettler et al., 2014). For this purpose, numerous possible evaluation methods exist (Cleven et al., 2009), while there are characteristics of artifacts favoring the use of specific methods (Peffers et al., 2012).

Furthermore, evaluation methods are classified into naturalistic and artificial forms (Venable et al., 2012). The former are constituted of human practices in real-life environments, while the latter are based on artificial scenarios. A reported problem with naturalistic forms of evaluation (e.g. case studies, subject-based experiments, expert interviews) is that too specific a context plus subjective opinions of individuals may influence the generalizability of the results (Peffers et al., 2012). Even if there are approaches to generalize such results (see e.g. (Lee and Baskerville, 2003)), we favor the use of an artificial form of evaluation. According to Hevner et al. (2004), simulation is a possibility to experimentally execute an artifact by means of artificial data, which is selected for evaluating the artifact under consideration, namely BPI-Pattern instances. Simulation in particular allows for the evaluation of BPI-Patterns in different scenarios, specified by controllable context variables. In combination with a high number of replicable simulation runs, this leads to a solid data pool for further analysis.

4 Business Process Simulation Methodology

Shannon (1998) defines simulation as "*the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system.*" Further, a simulation provides quantitative information that can be used for analyzing business processes (Hlupic and Robinson, 1998). In doing so, basically, performance measures of "as-is"-processes are compared with those after applying BPI-Patterns on the processes ("to-be") (cf. (Aguilar et al., 1999)). Thus, a simulation enables to record the performance of the simulated issue for a number of alternative process variations, which enables a comparison of these alternatives (Hillier and Lieberman, 2001), e.g. provoked by the application of BPI-Patterns. Simulation is flexible in terms of the investigated objects and demanded issues (van der Aalst and Voorhoeve, 2010). Hence, it is possible to evaluate a variety of objects by many different issues in a simplified manner. The possibility to test designs, organizational structures, etc. without committing resources or disrupting the ongoing operations is an additional advantage (Shannon, 1998). As a result, bottlenecks in information, material and product flows can be identified, which might be helpful to increase the performance of flow rates (Shannon, 1998). To carry out a process simulation experiment, the use of computer software as a tool is recommended (Davis et al., 2007).

There are several approaches to conduct a simulation experiment with a focus on business processes. By means of a representative literature search, the five most-prominent references were found which provide an incremental procedure for this purpose. Table 1 illustrates the condensed steps that were identified in these approaches.

No.	Step \ Author	Davis et al. (2007)	Hlupic and Robinson (1998)	Maria (1997)	Shannon (1998)	van der Aalst and Voorhoeve (2010)
1	*Problem Definition*			X	X	X
2	*Research Question*	X				
3	*Experimental Design*	X	X	X	X	X
4	*Data Collection*		X	X	X	
5	*Simulation Model Development*	X		X	X	X
6	*Model Validation*	X	X	X	X	X
7	*Simulation*	X	X	X	X	X
8	*Analysis and Interpretation*	X	X	X	X	X

Table 1. Overview of Business Process Simulation Methods

To ensure a comprehensive simulation methodology, all of the distinct steps are adopted in the simulation of BPI-Patterns. It starts with the identification of the problem definition (1) and the resulting research question (2). Then, the general setup and the simulation approach are determined and the process is modeled (3). After that, process-related data are collected (4), and integrated into the simulation model (5). This simulation model is validated by performing test-runs (6). Subsequently, the actual simulation is carried out (7) and the results are analyzed and interpreted (8). According to this eight-step-methodology, the simulation of BPI-Patterns is performed and presented in the next section.

5 Simulation

5.1 Application of the Simulation Methodology

The simulation experiment is based on the use of several input parameters, which are listed in Table 2. To achieve realistic results, it includes four processes, directly stemming from the daily work routines of a university's deanery (see section 5.3). In the considered processes, there are four different roles or groups of persons who are in charge of the particular activities, with professors again being associated with one department each (business administration, economics, information systems, real estate management). For determining the average costs per activity, the monthly salary of the performer is taken as a basis. Three BPI-Patterns (see section 5.2 for details), which are applicable to the processes at hand and suitable for simulation, are analyzed in separate simulation runs. Further simulation parameters include the timeframe of 100 or 150 days, with 10 to 30 instances passing the processes each day. The inter-arrival time of single instances is t-distributed whereas the processing time of activities is normally distributed. In accordance with the actual facts, entry conditions at activities are determined as FIFO (first in, first out), meaning that instances with the oldest timestamps are processed first. All simulation runs were conducted using the tool Bonapart (Version 6.1).

As illustrated in Table 3, the simulation scenarios differ regarding the ratio of instances, which are either simple or complex cases, handled by a process. This is expressed by the probability values allocated to exclusive OR-decisions (XOR-Rule) that determine the frequency by which alternative outgoing process paths are passed through. In scenario 1, the ratio is balanced (e.g. 50/50 for decisions with 2 outgoing paths) whereas in scenario 2, the time-consuming activities are performed in 90% of

Attribute		Values (Input Parameters)			
Process	Name	Email Support for Applicants	Application for Degree Courses	Qualification Assessment	Objection
Process	Roles	Study Coordinator	Mailman	Clerk	Professor (BA, Econ., IS, REM)
Process	Cost Rate	Low	Medium		High
BPI-Pattern		Assign Activities to external Parties	Automate Activities based on predefined Rules		Parallelize Activities in sequential Process Flow
Simulation Parameter	Timeframe	100 days		150 days	
Simulation Parameter	Instances / Day	10	15	20	30
Simulation Parameter	Inter-Arrival Time	t-Distribution			
Simulation Parameter	Processing Time	Normal Distribution			
Simulation Parameter	Entry Condition	First in, First out (FiFo)			
Simulation Parameter	Simulation Tool	Bonapart (Version 6.1)			

Table 2. Simulation Overview and Input Parameter

all process runs, the less time-consuming ones only in 10%. For example, considering an application process, in scenario 1 there are 50% international (more time-consuming) and 50% domestic (less time-consuming) applicants, while in scenario 2 the ratio is 90% to 10%. Scenario 3 is the exact opposite of scenario 2: 10 % for the time-consuming activities as opposed to 90 % for the less time consuming-ones. Scenario 4 is based on empirical data for each process as observed in reality. Similarly, probabilities are determined for XOR-decisions with three alternative process paths.

Attribute	Values			Scenario							
	Probability in case of…	2 outgoing paths	3 outgoing paths	1	2	3	4	5	6	7	8
Ratio of different Instances	balanced	50/50	33/33/33	X				X			
	emphasis on complex cases	90/10	90/5/5		X				X		
	emphasis on simple cases	10/90	5/5/90			X				X	
XOR-Rule	based on historical data	(individual)	(individual)				X				X
Personnel Resources	1 Person per Role			X	X	X	X				
	2 Persons per Role							X	X	X	X

Table 3. Characteristics of the eight simulated Scenarios

Another distinguishing characteristic are the personnel resources assigned to a role that leads to different options e.g. concerning the scheduling of work. Scenarios 5 to 8 correspond to the first four scenarios, with the one exception that the number of staff in charge for performing process activities is twice as high. In scenarios 1 to 4, there is only one employee performing a specific activity, whereas in scenarios 5 to 8 there are two employees who can share the workload. In total, 112 different simulation runs (combination of process, BPI-Pattern, and scenario) are carried out, with every simulation run containing up to 3,000 process instances.

5.2 Overview of BPI-Patterns

Basically, in conducting this simulation experiment, activities or control flows of the business processes (see section 5.3) are modified. In compliance with the above-mentioned procedure, we selected the three BPI-Patterns “Assign Activities to external Parties”, “Automate Activities based on predefined Rules” and “Parallelize Activities in sequential Process Flow”. In so doing, we expected these three BPI-Patterns to result in positive effects on one or both of the relevant effect dimensions cost and time, whose evaluation is the main focus of this study. Potential effects on the dimensions quality and flexibility, which are generally also addressed by BPI-Patterns, are not subject of this simulation experiment. Nevertheless, one prerequisite for applying BPI-Patterns was that the two latter dimensions are not affected negatively. The central ideas of the selected BPI-Patterns and the way they affect the structure of business processes, as measured by the simulation, are discussed in the following.

Pattern 1: "Assign Activities to external Parties" suggests relocating activities that depend on input data by external sources and hence reducing the workload in a business process (e.g. entering of form data by an external person in a web interface). The quality of the output supplied by the external party has to be at least an equivalent of the former internally produced output of this activity. This process of outsourcing is expected to result in positive effects on processing costs and time.

The basic principle of **BPI-Pattern 2: "Automate Activities based on predefined Rules"** is that existing manually performed activities are replaced by an automation/IT-system-based component, which makes human input dispensable. The automation of activities is expected to lead to less processing time compared to manual performances of these activities. This especially makes sense if an activity is a frequently recurring standard task and can easily be automated providing constant output.

As the name of **BPI-Pattern 3: "Parallelize Activities in sequential Process Flow"** suggests, its purpose is to restructure the control flow within a business process so that previously sequentially performed activities are performed simultaneously. To enable this, the affected activities have to be independent from each other and corresponding personal resources have to be available. The prevalent effect from this parallelization is a reduction of the overall process cycle time, as former sequentially performed activities are performed simultaneously.

5.3 Overview of the Business Processes

In this section, the four business processes that were investigated in the simulation experiment are presented. All of them take place at a deanery of a German university and are part of the application procedure for specific degree courses. To show their structural characteristics, such as activities, associated roles, decision points, and process flow, detailed process models are provided in the appendix.

The process **"Email Support for Applicants"** is an important part of the application procedure. It contains the three most common types of email inquiries and is exclusively performed by the study coordinators. In detail, inquiries e.g. refer to the assessment of an applicant, contain questions regarding the organization of the application procedure, or refer to the modification of a previously transacted application. While the first two types of inquiries can be answered with a normal email-response, the last type of inquiry requires additional activities in the application tool. For example, a study coordinator may need to upload additional documents to include them in the application file.

The process **"Application for Degree Courses"** covers the handling of incoming application documents (e.g. CV, degree certificates, etc.) and is also exclusively performed by study coordinators. Depending on where an applicant is from, different formal requirements have to be fulfilled. In the case of a foreign applicant, additional documents (e.g. language certificates, etc.) need to be submitted and checked for completeness. If the documents are not complete, the applicant is contacted, if necessary, several times, until his/her documents are complete, in which case the application is marked valid in the online application tool and the documents are placed into an inactive file.

The **"Qualification Assessment"** of an applicant is performed on the basis of the documents handed in during the application and involves study coordinators, clerks, mailmen and a selection committee consisting of professors from different departments at the university. First, the eligibility of an applicant is examined by a member of the selection committee. If the expertise of an applicant is sufficient, his/her country of origin is checked. Domestic applicants receive a note of authorization right away, which is created and posted by the study coordinators. International applicants need to pass an additional formal check, which is carried out by clerks of the registrar's office (e.g. verification of certain language skills). If that formal check is not passed, international applicants are rejected and the process ends with sending a letter of rejection. If the formal check results in the certificates submitted being incomplete, the applicant is accepted on condition that s/he produces the missing certificates until a set deadline. After sending the particular notification the process is completed.

The fourth process handles an eventual **“Objection”** by an applicant whose initial application has been rejected. This is performed by the study coordinators and the professors of the selection committee. A valid objection must meet certain legal requirements (e.g. the objection must have been filed in written). If it is not legally valid in all aspects, a study coordinator contacts the applicant to demand an additional filing. In case of a valid objection, it is scanned and uploaded to make the document available for the committee member in charge. S/he rechecks the initial rejection letter, checks whether the objection is conclusively justified and makes a decision. Afterwards, it is communicated to the applicant in a respective notification created by the study coordinator.

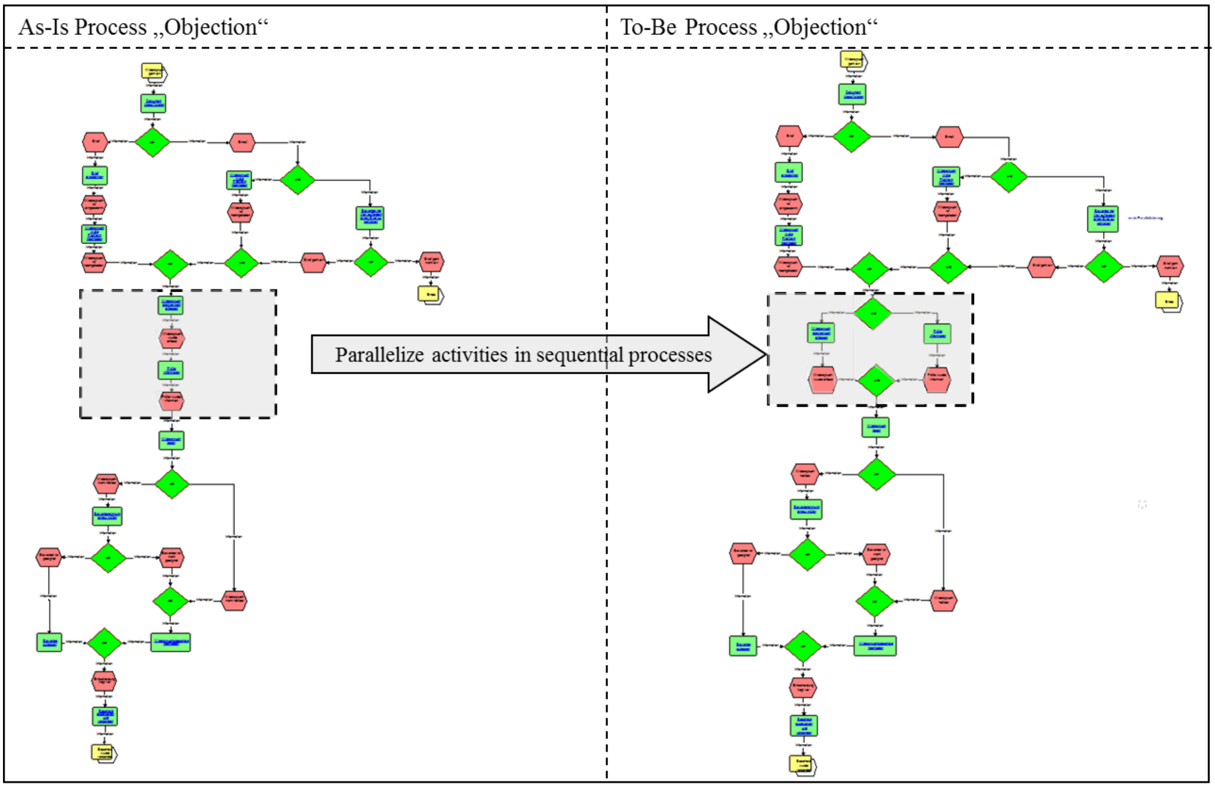

Figure 3. Application of BPI-Pattern “Parallelize Activities in sequential Process Flow”

Figure 3 exemplifies the change that is caused by applying the BPI-Pattern “Parallelize Activities in sequential Process Flow” on the process “Objection”, as highlighted in the two versions of the process (“as-is” and “to-be”). The two activities that formerly were performed consecutively are afterwards performed in parallel. In section 6, we present and discuss further findings resulting from carrying out the simulation experiment including all of the four business processes with the selected BPI-Patterns.

6 Results of the Simulation

Table 4 shows the results before and after applying each of the selected BPI-Patterns (columns) on the different processes (rows). For each process, eight different scenarios are simulated. The focus of the investigation is on cycle times, processing times, waiting times, and costs. For these performance indicators, the mean values are calculated and included in the cells of the table. For example, considering the process “E-Mail Support”, after applying BPI-Pattern “Assign Activities to external Parties” in scenario 1, the cycle time is 12:18 minutes (min.). As described in section 5.1, the scenarios mainly differ regarding the allocation of personal resources for activities. The reason for the blank cells in the column “Parallelize Activities in sequential Process Flow” is that parallelizing activities is only applicable in scenarios where at least two persons are available for executing parallelized activities.

		Standard				Pattern											
						Assign Activities to external Parties				Automate Activities based on predefined Rules				Parallelize Activities in sequential Process Flow			
Process	sc \ ind	Cycle Time	Pro-cessing Time	Wai-ting Time	Costs	Cycle Time	Pro-cessing Time	Wai-ting Time	Costs	Cycle Time	Pro-cessing Time	Wai-ting Time	Costs	Cycle Time	Pro-cessing Time	Wai-ting Time	Costs
E-Mail Support for Applicants	1	12:42	04:54	07:32	1.91	12:18	04:39	07:21	1.81	06:14	02:55	03:14	0.82				
	2	19:45	07:52	11:26	3.06	19:15	07:48	10:59	3.04	07:22	02:02	05:15	0.39				
	3	09:32	03:23	05:59	1.32	09:33	03:20	06:02	1.30	10:09	04:02	05:58	1.17				
	4	15:10	05:57	08:57	2.32	14:12	05:32	08:24	2.15	07:56	02:31	05:21	0.58				
	5	10:51	04:54	05:40	3.81	10:05	04:29	05:23	3.49	07:31	02:54	04:26	1.46	10:48	04:57	06:47	3.85
	6	14:15	07:52	05:54	6.13	14:01	07:48	05:48	6.07	07:19	02:01	05:13	0.77	14:11	07:55	08:09	6.16
	7	08:51	03:23	05:19	2.64	08:58	03:21	05:28	2.61	09:31	04:02	05:20	2.34	08:51	03:23	06:02	2.64
	8	11:44	05:43	05:41	4.48	11:14	05:27	05:30	4.24	07:47	02:31	05:14	1.16	11:45	05:49	07:14	4.53
Application for Degree Courses	1	08:07	03:15	04:37	1.27	08:14	03:19	04:38	1.29	07:44	03:02	04:27	1.18				
	2	25:01	08:45	15:31	3.41	26:22	08:54	16:34	3.47	15:50	06:15	09:04	2.44				
	3	07:56	03:25	04:16	1.33	07:58	03:27	04:15	1.33	07:56	03:25	04:16	1.33				
	4	06:45	02:31	04:00	0.98	07:49	03:28	04:09	0.99	06:48	02:32	04:06	0.98				
	5	06:55	03:11	03:28	2.48	06:49	03:13	03:26	2.51	05:42	02:59	02:34	2.33	06:54	03:11	03:43	2.48
	6	13:51	08:36	04:35	6.70	14:06	08:55	04:30	6.94	10:30	06:13	03:47	4.84	13:56	08:35	06:13	6.68
	7	07:09	03:26	03:29	2.67	07:20	03:32	03:28	2.72	07:11	03:25	03:32	2.67	07:09	03:26	03:42	2.67
	8	06:09	02:31	03:26	1.99	07:10	03:25	03:28	1.97	06:10	02:33	03:27	1.98	06:08	02:31	03:33	1.96
Qualification Assessment	1	14:38	07:10	06:55	14.48	14:59	07:51	06:04	10.71	13:48	05:05	07:45	13.84				
	2	42:56	20:47	19:08	18.73	14:35	08:05	15:05	9.62	15:21	06:18	16:03	14.33				
	3	07:25	04:07	03:02	13.56	12:41	08:24	03:13	16.12	08:50	04:05	04:24	13.51				
	4	08:47	05:16	02:35	13.98	11:33	06:23	04:40	7.10	09:40	04:48	04:27	13.77				
	5	13:00	07:18	04:24	29.19	13:34	07:52	04:29	23.10	11:57	05:01	06:02	27.68	09:58	07:06	02:40	28.96
	6	32:37	21:10	06:50	37.74	16:06	08:02	04:20	15.88	11:32	06:22	03:55	28.81	29:12	20:40	07:44	37.49
	7	07:27	04:07	03:02	27.14	11:58	08:21	02:34	32.55	09:33	04:08	05:15	27.10	07:48	04:05	03:34	26.90
	8	08:04	05:13	02:31	27.85	11:40	06:25	04:56	14.72	08:11	04:46	03:23	27.56	11:40	05:21	05:49	27.82
Objection	1	48:51	18:18	40:49	9.06	27:07	12:18	18:29	6.32	30:47	12:40	24:03	6.82				
	2	54:41	17:46	37:17	9.16	34:54	14:33	19:34	7.60	40:04	14:21	26:29	7.85				
	3	36:17	13:24	29:53	6.47	17:14	08:25	08:01	4.37	27:15	09:45	16:15	5.03				
	4	48:14	15:26	36:33	7.51	43:40	14:17	28:18	6.99	29:30	13:16	27:49	7.24				
	5	49:57	16:49	41:39	16.96	26:11	12:04	17:06	12.45	30:11	12:28	22:00	13.48	46:19	16:34	45:57	16.05
	6	49:35	17:42	31:07	18.26	34:53	14:33	19:34	15.19	40:04	14:21	26:30	15.70	51:37	17:41	44:52	18.23
	7	36:52	13:14	29:42	12.80	16:31	08:24	08:01	8.72	21:30	09:49	16:05	10.10	33:59	13:17	37:45	12.85
	8	47:07	15:29	35:45	15.02	44:25	14:16	25:43	13.94	31:57	13:31	29:15	14.69	46:46	15:22	44:01	14.96

Key: sc = Scenario, ind = performance indicator; Times in mm:ss; Costs in €

Table 4. Results of the Simulation (highlighted values discussed in the text)

6.1 Pattern 1: Assign Activities to external Parties

The idea of this pattern is to assign a former internal activity to external parties. Thus, positive effects on time and cost dimensions are expected. When, for example, applied to the process “Objection”, the activity of scanning the objection, originally performed by the study coordinator, was assigned to the sender. Hence, rejected applicants are asked to file their objection by letter and email simultaneously. As the scanning activity takes about 3 min., average time savings of about 3 min. were expected as a result of the performed simulation runs. Contrary to this expectation, the simulation results show both positive and negative effects on the dimension time. The differences between the “as-is” and the “to-be” processes either are manifested in large or hardly any savings. In scenario 1, for example, an average cycle time of 48:51 min. was measured for the “as-is” process, compared to an average cycle time of 27:07 min. for the “to-be” process option, thus a time saving of 21:44 min. could be achieved. Similar savings could be noticed for the scenarios 2, 3, 5, 6 and 7. Within these scenarios, most of the instances traverse the improved part of the process, where the pattern has been applied. Scenarios 4 and 8 show fewer time savings. So the “to-be” cycle time of scenario 4 of 43:40 min. is only 4:34 min. shorter than the “as-is” cycle time of 48:14 min. Here, as the rejected applicants still send their written objections, the study coordinators again need to scan in these letters.

The application of this BPI-Pattern reveals the biggest savings, considering cycle times, for the process “Qualification Assessment” of about 66%, down from 42:56 min. to 14:35 min. in scenario 2. Further, a great reduction of processing time is possible down from 21:10 min. to 08:02 min. (62%) in scenario 6, which also holds for the costs (from 37.74 € down to 15.88 € per process run). In all scenarios of the process “Objection”, the highest possible reduction of the waiting time is 73% (from 29:53 min. down to 08:01 min.).In contrast, other applications of the pattern show negative effects for all performance indicators as well, e.g. an increase of the cycle times in the process “Application for degree courses” from 06:09 min. to 07:10 min. or an increase of waiting times in the process “E-Mail Support for Applicants” from 05:19 min. to 05:28 min.

All results regarding the BPI-Pattern “Assign Activities to external Parties” show divergences between the scenarios where the use of the pattern caused additional work to (re-)integrate the output of out-sourced activities. Further analysis revealed that cycle times, processing times and costs are affected in a negative way. Besides, the additional processing times increase the danger of queues building up. The expected savings can only be achieved, if the scope of the rework is less than the savings.

6.2 Pattern 2: Automate Activities based on predefined Rules

The goal of this pattern is to replace manually performed activities by automated ones. As for the previous pattern, positive effects on times and costs are expected as well, especially due to a reduction of processing times of activities being affected by the pattern.

In the process “Objection”, the study coordinator has to inform the professors in charge that s/he must review the available documents again. After applying the pattern “Automate Activities based on predefined Rules”, the change results in the responsible professor being informed automatically right after the objection document is online. In detail, the activities of selecting the professor in charge and creating an e-mail about the objection are carried out simultaneously. Additional work is not necessary to perform the to-be process. Thus, a reduced cycle time of about 2 min. is expected. A decrease in cycle, processing and waiting times is noticeable in all scenarios in the process “Objection”. At its best, a cycle time saving of 15:22 min. (42%) in average is achievable in scenario 7 (from 36:52 min. down to 21:30 min.). This positive effect originates from a reduction of waiting times. Cost savings are equivalent to processing times with a maximum decrease of 25% in scenario 1.

For pattern “Automate Activities based on predefined Rules”, greater savings in cycle times are also achievable in the process “E-Mail Support for Applicants” with a decrease from 19:45 min. down to 07:22 min. (62%) in scenario 2. Under these circumstances, also the processing time drops significantly by about 74% (from 07:52 min. down to 02:02 min.) together with the waiting time (54%, from 11:26 min. down to 05:15 min.) and costs (87%, from 3.06 € down to 0.39 €). In contrast to the processes “Objection”, “E-Mail Support for Applicants” and “Application for Degree Courses”, negative effects appear in the process “Qualification Assessment”. In scenario 7, an increase of cycle time from 07:27 min. up to 09:33 min. (28%) is measured. The reason for this is a bottleneck emerging in a subsequent sector of the process because of the automated activity.

Summarizing, the BPI-Pattern “Automate Activities based on predefined Rules” predominantly shows positive effects. The success of applying this BPI-Pattern is tied to similar conditions as in the case of the BPI-Pattern “Assign Activities to external Parties”. Thus, if the automation accounts for additional activities (e.g. preparation tasks to transform input in machine-readable format) savings can be mitigated. In all simulation runs, cost savings correspond to the processing time savings.

6.3 Pattern 3: Parallelize Activities in sequential Process Flow

This pattern aims at restructuring process parts consisting of sequential activities that are independent of each other. Thus, the activities can be performed simultaneously (see Figure 3). After applying this pattern, only the more time-intensive path is critical for the cycle time. Since the duration of the shorter path can be saved, a reduction of the cycle time is expected. As the processing time for the parallelized activities does not change, costs are not expected to change either.

In the as-is process "Objection", the activities of uploading the objection letter and informing the professor in charge is performed sequentially. After applying the BPI-Pattern "Parallelize activities in sequential process flow", these two process steps are performed in parallel. Further changes to the process, e.g. additional coordination work, are not necessary. In scenario 7, a decrease of cycle time from 36:52 min. down to 33:59 min. (8%) occurs. In the worst case (scenario 6), an average process run takes about 4% longer than in the as-is process.

Considering all processes, the best and worst effects can be seen in the process "Qualification Assessment". In scenario 5, the cycle time is reduced by about 23% (from 13:00 min. down to 09:58 min.) and the waiting time decreased by about 39% (from 04:24 min. down to 02:40 min.). In contrary, the cycle time increased by about 45% (from 08:04 min. up to 11:40 min.) in scenario 8. The processes "Application for Degree Courses" and "E-Mail Support for Applicants" show hardly any changes concerning cycle time while the waiting time increased by up to 40% (from 05:19 min. up to 06:02 min.).

In summary, the BPI-Pattern "Parallelize Activities in sequential Process Flow" only marginally affects both processing time and costs. The cycle time is mainly positively affected, whereas the waiting time is often negatively affected as personal resources may not be available at the same time.

7 Implications for BPI-Patterns

This section outlines the insights regarding the factors we gained by executing the simulation, which either concern all patterns or relate to specific patterns. Moreover, it highlights implications for extensions of the pattern descriptions. Table 5 gives an overview of the enabling and hindering factors which were identified for the considered BPI-Patterns in the simulation experiment. Such factors were found both for the process context as well as for the structural characteristics of the process itself. In general, for every process containing alternative process paths (XOR), the effectiveness of each BPI-Pattern depends on the frequency of the instances passing through the particular process path that is affected by the BPI-Pattern. In case this portion is rather low, the positive effect of a pattern is diminished. Moreover, the application of a BPI-Pattern that optimizes solely one specific process path may even lead to negative results regarding the whole process. Therefore, when selecting BPI-Patterns, the user has to carefully take into consideration if the application of a pattern impacts the whole process. As a rule, one should prefer deploying BPI-Patterns at such points within the process where the majority of the process instances are affected.

7.1 Pattern 1: Assign Activities to external Parties

This pattern suggests changing the process in such a way that external parties are in charge of performing several activities. One hindering factor is that in some cases additional coordination work (e.g. quality assurance of external input) is necessary if the pattern is utilized.

Regarding these insights, heuristics can be provided which help to decide under which conditions a pattern is likely to be useful. First, the tradeoff between cost/time savings and additional coordination work caused by the outsourcing has to be considered. Second, it is observed that the best results are achieved when the outsourced activities are either at the beginning or at the end of a particular business process: e.g. data entry carried out by the customer before the start of the actual process. In contrast, the outsourcing of activities in the middle of a process leads to increased waiting times since, in this case, additional interfaces are created, which is a hindering factor. Third, it is noticed that the bigger the process part being outsourced the better the cost-benefit ratio. Fourth, activities that are candidates for outsourcing should be standardized or easily explainable to the external party. Also, they should be the same for all process instances, showing no variants.

	Factor	Enabling	Hindering
Pattern 1: Assign Activities to external Parties (see section 5.2)	Tradeoff: cost/time savings vs. coordination		Additional coordination work (e.g. quality assurance of external input)
	Process structure	Applying the pattern at the beginning or end of the process (less integration effort)	Applying the pattern in the middle of the process (more integration effort)
		Assigning coherent larger process parts to external parties	
	Complexity of reassigned activities	Standardized/easy explainable activities without variants	Complex activities
Pattern 2: Automate Activities based on predefined Rules (see section 5.2)	Machine readable data	Availability of machine readable input	
	Process structure	Applying the pattern at the beginning or end of the process	Applying the pattern in the middle of the process
		Automation of coherent larger process parts	
		Automation of activities which are part of the critical path in the process	
	Resources	Allocation of sufficient resources to the process part following the automated section	No reallocation of resources leads to increasing waiting times overcompensating the savings in processing times
Pattern 3: Parallelize Activities in sequential Process Flow (see section 5.2)	Process structure	Parallelizing activities which have similar processing times	
		Parallelizing activities which are part of the critical path in the process	
	Resources	Availability of autonomous resources, able to work on the same process instance at the very same time (synchronization) in the parallelized process part	Allocation of resources in charge of further activities beyond the parallelized process part, so that the parallelized activities are not performed at the same time

Table 5. Overview of enabling and hindering factors for the applied BPI-Pattern

7.2 Pattern 2: Automate Activities based on predefined Rules

By using this pattern, several activities are automated; hence the savings in regard of processing times and costs are to be expected. The pattern usually accelerates a certain part of the business process because the processing time of automated activities is much shorter compared to the former manual execution. An important factor that enables automation is the availability of machine-readable input. Nevertheless, the automation of only a part of the process may lead to the creation of new bottlenecks subsequent to the automated activities. Since the incoming rate of successive activities increases, sufficient resources have to be provided. Otherwise, waiting queues will occur and, in consequence, waiting times increase. This effect may lead to negative results, e.g. that the emerging waiting times will overcompensate the reduction in processing time and therefore lead to longer cycle times.

As a consequence, the requirements, as described in the element “context” of the BPI-Pattern (see data model in Figure 1), should be extended. An additional requirement for the successful application of the pattern is that the part of the process that follows the automated section has to be capable of keeping pace with the increased throughput. In concrete terms, the subsequent activities need to have sufficient resources (enabling factor) allocated to them. Only that way will the enhancements, being achieved by automating activities, lead to a reduction of overall cycle times.

7.3 Pattern 3: Parallelize Activities in sequential Process Flow

The application of this pattern resolves sequences of independent activities and allows for their parallel execution. However, the simulation shows ambiguous results especially in respect to cycle time and waiting time. These inconclusive findings might be explained by the fact that in the processes at hand the exact routing of the single cases is not determined, i.e. it cannot be guaranteed that the activities that are supposed to be executed in parallel are indeed performed at the very same time because the staff resources are in charge of more than one activity and thus may possibly not be available at a specific point of time (hindering factor). This problem is related to the fact that people in back office processes are usually free to organize their work. For a successful application of the pattern in terms of reducing cycle time, it is crucial that all parallelized activities related to one instance (e.g. a specific application) are executed simultaneously allowing subsequent activities to start without additional waiting time. Thus, it is necessary that employees are available at the same time and the new process design ensures the synchronization of the parallelized activities by providing explicit routing strategies (e.g. workflow management, just in time system, etc.).

When parallelizing activities, the cycle time of the process always depends on the length of the critical path, i.e. the process path with the longest processing time. For that reason, putting those activities in parallel that have similar processing times is an important enabling factor when aiming for shortening overall cycle times. Otherwise, having a rather short activity in parallel with a much longer activity will in fact lead to buffer time - while one process path is waiting for the completion of the other process path - and the effect on total cycle time will even be only marginal.

8 Conclusion

The purpose of the simulation experiment is to evaluate whether the BPI-Patterns show their anticipated effects when being applied to different business processes and scenarios. In this particular case, we investigated a series of connected business processes covering the application procedure for specific degree courses processed by a university's deanery. The underlying aim was to analyze changes in the manageable effect dimensions "cost" and "time", also providing the basis for selecting applicable BPI-Patterns from a repository. In so doing, three BPI-Patterns complying with these requirements were selected. In addition, a simulation procedure was derived from literature that meets the requirements for being used to simulate business processes. The simulation setup included different parameters (e.g. instances/day, timeframe, etc.) as well as scenarios that determine the control flow of business processes (e.g. conditions for outgoing paths).

After carrying out the simulation, the analysis of the results concentrated on the changes of cost and times of the processes before and after the application of the BPI-Patterns. Our results show that the examined patterns do bring about the intended positive effects in most cases (see Table 4). They also confirm that the underlying assumptions about the patterns' functioning are valid. However, it did also become apparent that the extent to which the effects occur widely varies across different processes and scenarios. We found cases in which particular BPI-Patterns even lead to negative results. These observations are contrary to the effects predicted by the BPI-Pattern. Thus, it is crucial to be aware of both enabling and hindering factors of successful applications (e.g. parallelizing activities with nearly equal processing time). We derived suggestions to specify existing pattern descriptions by adding the identified factors, serving as heuristics for the selection of suitable BPI-Patterns in a given case.

This research is not without limitations. In evaluating the validity of the anticipated effects of a BPI-Pattern, we only focused on cost and time, as these two dimensions are the most suitable ones for our simulation experiment. The two remaining dimensions, quality and flexibility, were not subject of this study. Furthermore, all of the processes lie within one specific sector (university administration), which restricts the generalizability of the simulation results.

In future research, the findings from this paper will be used for a refinement of BPI-Pattern instances, i.e. for the revision of the contents of BPI-Patterns. Along with carrying out further simulation experiments in other contexts, we intend to focus on a potential modification or supplementation of the underlying data model of BPI-Patterns, which, in turn, would affect all of the BPI-Pattern instances. Applying BPI-Patterns in other scenarios will be part of our effort to provide further evidence of the significance und usefulness of BPI-Patterns to be used within a BPI initiative.

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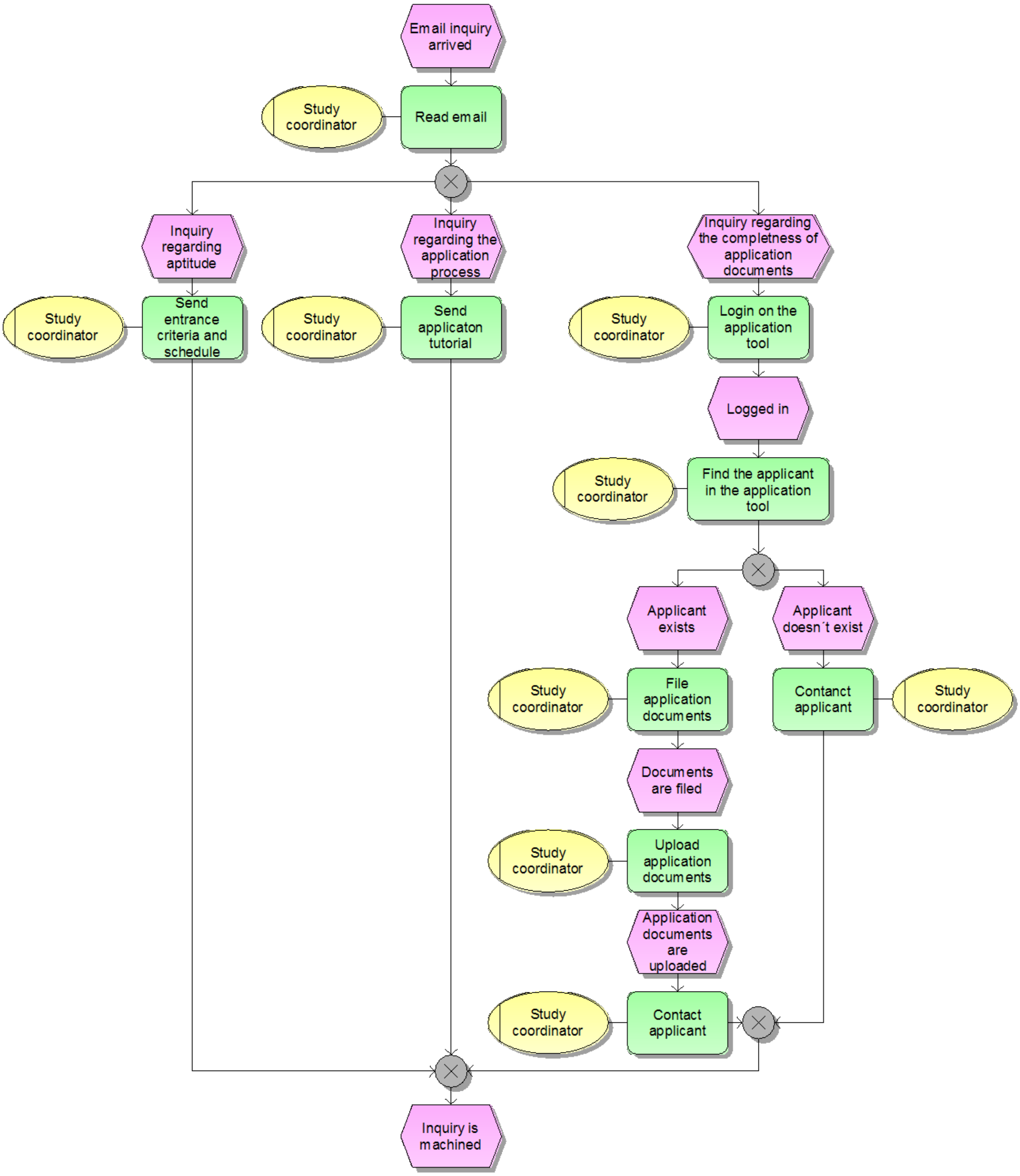
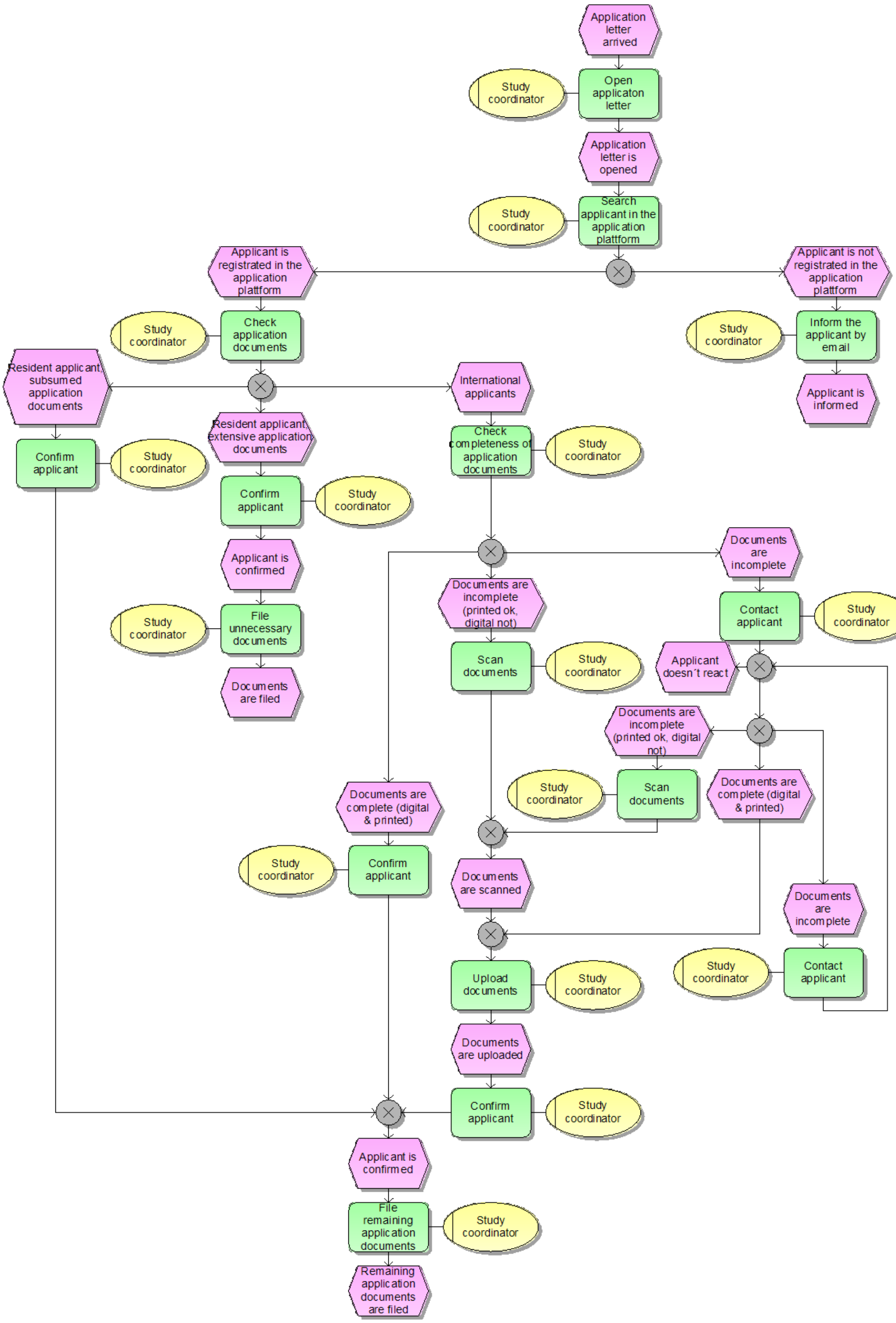
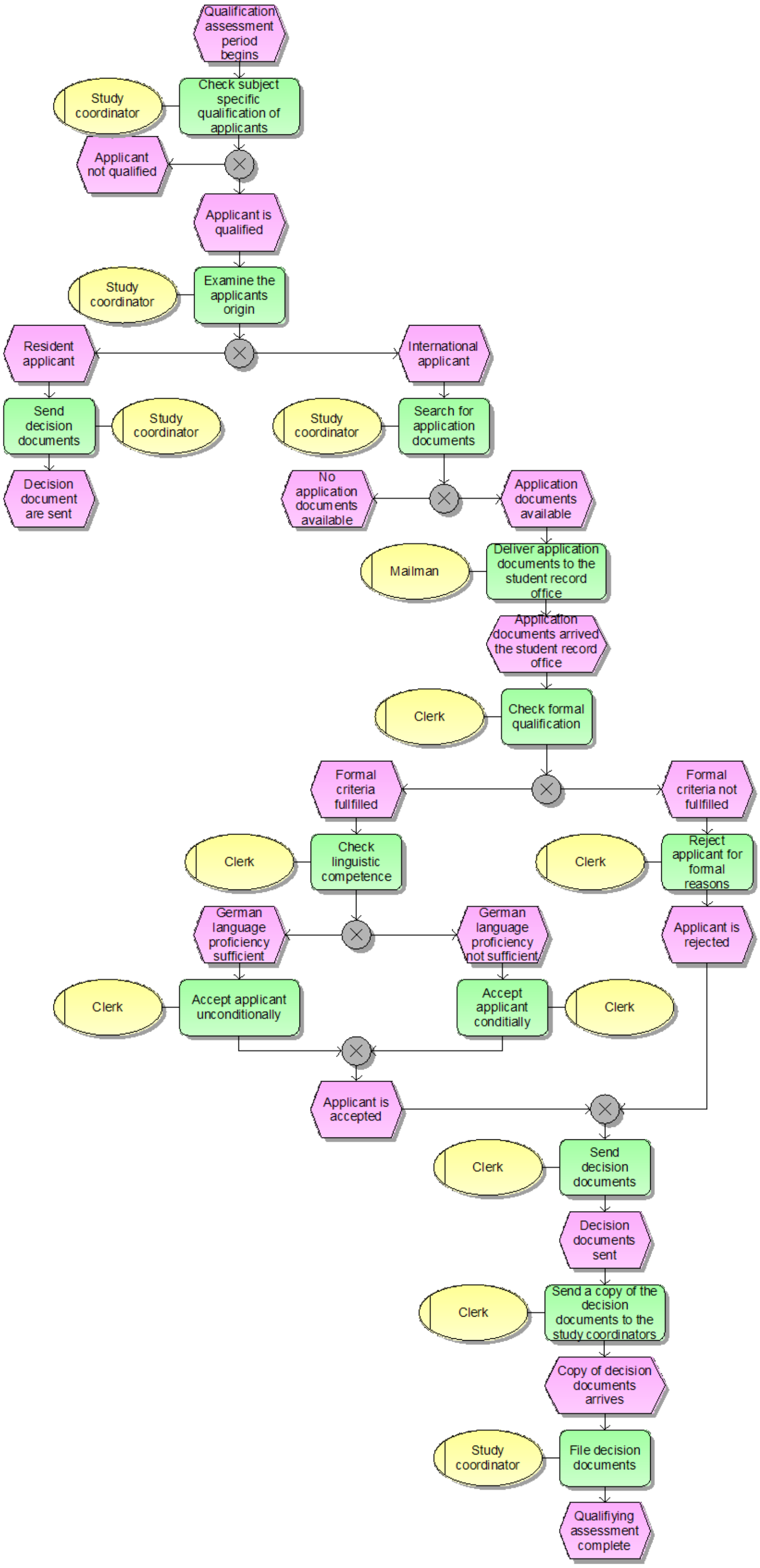
Appendix A: Process Model "Email Support for Applicants"



Appendix B: Process Model "Application for Degree Courses"



Appendix C: Process Model "Qualification Assessment"



Appendix D: Process Model "Objection"